THE ATTAINMENT AND COST OF PLACER MINING EFFLUENT GUIDELINES

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DEPARTMENT OF FISHERIES & OCEANS

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SUMMARY AND COST ESTIMATES

This brief proposes ways in which placer miners may be able to obtain standards of 1000, 100 and zero suspended solids in wash water coming from their operations. Included are estimated costs of construction, purchasing and operation. A number of assumptions were made about Yukon placer mining in order to arrive at a typical operation and the methods used to treat its effluent. The assumptions are the size of the operation, the settling ability of the silts and clays in the wash water and the percentages of each, and the efficiency of water use in sluicing. All the estimates use conservative figures so that an individual miner may find his costs will be lower. The reader should compare these estimated costs with those reported for several British Columbia placer mining operations given on pages 23 to 28. Finally the reader will be aware that there is no 'typical' placer mining operation. Treatment method and costs will depend a great deal on site-specific characteristics of each claim.

The brief does not attempt to cost treatments for operations washing relatively large volumes of pay gravel, or those operations which through size classification at the dumpbox are able to make very efficient use of their water. The efficiency of water use can reduce treatment costs considerably, for the size of settling ponds can be made smaller in area and less costly. The brief assumes that figures for water duty to the sluice and the volumes mined are attained on a daily basis for a 90 day mining season. All costs are based on a mining rate of 70 cubic yards of pay gravel per hour using 4000 gallons per minute of water, for a 7.5 hour mining day.

There are three treatment schemes. In all cases the miner needs to construct a primary settling pond to receive all sediments carried away by the wash water from the coarse tailings. This first settling pond is estimated to have sufficient retention time to settle coarse silts, but not the clays and finer silts. The primary pond is planned for 45

days' operation or half the mining season before it has to be either replaced by another or cleaned out with heavy equipment. It is impractical to build a primary pond to operate for a full season, as too deep a basin would be needed. Depending on the size of bulldozer used, this primary pond would cost between $1500 and $3000. Emptying the pond or building a new one after 45 days would cost about the same.

The secondary pond for 1000 mg/l has to be much bigger than the primary pond, since it needs to have at least 18 hours retention time and the water flow to it is quite large. However it does not need to be deep and its cost of construction is less than that of the primary pond; $1000 to $2000.

Attaining a suspended solids limit of 100 mg/l calls for a modification to the 1000 mg/l system by the addition of recirculation of sluice water. The primary pond is the same. At its outlet, a pump needs to be installed to return part of the flow back to the sluicebox. The secondary pond can be smaller than for the 1000 mg/l system because it has to treat a smaller volume of water, however it has to store the same volume of fine silt and clay produced, and this means that it will be deeper and more costly. For a 50% recirculation system, the capital cost in addition to the primary ponds above would be $17,000 for the pump and piping and between $2000 and $4000 for the secondary pond. For a recirculation of 87%, capital costs would be $20,500 and pond costs would be between $5000 and $10,000.

Finally, in the case of a zero effluent creek, the miner would have the above costs and an additional cost of a secondary pump, to return water from the secondary pond outlet back to the sluice. These costs for a 500 IGPM pump and piping are estimated at $12,000.

Cost Breakdowns Can Be Summarized

	1000 mg/l	100 mg/l	0 mg/l
Primary pond (X2)	$ 5000	$ 5000	$ 5000
Secondary Pond	1500	7000	7000
Recirculation Pump 87%	-	20500	20500
Secondary Pump	-	-	12000
	$6,500	$32,500	$44,500

Another estimate of costs can be made by the above plus the hourly costs for the pumps to arrive at a total cost per yard mined, assuming 70 yds^3/hr for 90 days, or 47,250 yds.

	1000 mg/l	100 mg/l	0 mg/l
Primary Pond	$ .11	$ .11	$ .11
Secondary Ponds	.03	.15	.15
Recirculation	-	.34	.34
Secondary Pumping			.24
Cost per yard	$ .14	$ .60	$ .84

These costs will increase somewhat if the miner uses more than 4000 IGPM, or if more than an average of 70 yds^3/hr are mined. They cannot be made more definitive without gathering much more accurate information on placer mining operations, particularly on the clay contents of pay gravels and the mining efficiencies.

Some operations may have to use flocculants to attain a 100 mg/l or a zero standard. This is because the property may not have the room to build the ponds that have been estimated or because the clay content is too high to permit adequate settling. The costs of treatment are not high. A 500 IGPM flow may need a dose as small as 1/2 part per million to settle the fine silts and clays, and the cost for that amount could be less than one cent per yard washed. No elaborate system is needed to add the material in that a dispersing system can be built from

scrap. Efficient flocculant addition will however require building a dam at the outlet of the primary pond (or the secondary pond) where the flows can be accurately measured.

A final comment concerns the monitoring of suspended solids in effluent or at any stage in the system. It is proposed that miners be encouraged to use hydrometers in conjunction with conversion charts so that they can estimate suspended solids concentrations. Hydrometers are available which are sufficiently accurate to measure suspended solids concentrations to within 200 mg/l. Miners should also be encouraged to understand sedimentation processes and the use of the Imhoff cone so that they can monitor the efficiency of their settling system and recycling systems.

TAILINGS PONDS FOR 1000 mg/l

Tailings ponds with or without recycle seem to be the best practicable method for removing high suspended sediment loads from placer gold sluice water. Two types of pond are proposed, a primary or recycle pond to settle fine sands and coarse silt, and a secondary pond for fine silts and clays. Factors to be considered in designing these ponds are the quantity of gravel being washed and its fines content, and the volume of water passing through the ponds. The pond has to be large enough to store the sediment load without frequent removal, and secondly, the pond has to have a sufficiently long retention time and a low internal water velocity so that the suspended sediments can settle out.

The speed at which a small rock or mineral particle sinks down in water depends on the size of the particle; fine silts will take longer to settle through a metre of water than coarse silts. This speed or settling velocity also depends on the temperature, and whether or not the water has a high loading of finer particles such as clays which will settle very slowly. For a pond to be effective it must have a retention time long enough to allow the particle to settle to the sludge layer. In other words, if a 50 micron silt particle needs 10 minutes to settle one metre, then the water must reside in the pond for 10 minutes. Retention time can be estimated by dividing the total water volume stored by the inflow in minutes.

It is not practical to build a system in the hope that all the particles will settle in one pond - an efficient system must have two ponds and for placer mining uses, this will be cheaper than building one. All the fine sand and silt after settling out of the sluice water will occupy more space in the pond than it did in the dry state. Pay gravel weighs about two metric tonnes per cubic metre (124 lbs per cubic foot, or 3370 lbs per cubic yard). But as freshly-deposited sediment, with coarse sand and clays being deposited elsewhere, it will weigh only 1500 kg/m^3 (94 lbs/ft^3). The coarse sands will be stacked with gravels as tailings, and the clays will not settle in the

primary pond. The most important factor in deciding on the size of the primary pond will be the amount of material that has to settle in it, and not the retention time.

The secondary pond is designed for a different purpose; it has to settle medium and fine silts and clays that pass through the primary pond. Since the amount of these fines in pay gravel is not large (less than 5% for most operations) the volume they will occupy on settling is less important than the time they need to settle. So the secondary pond has to have a much higher retention time than the primary. This does not mean that the secondary pond will be more expensive, because it can be quite shallow.

For the purpose of estimating the costs of primary and secondary ponds, a 'typical' small placer operation has to be invented. Estimates will use an operation that sluices 70 cubic yards per hour, using 4000 gallons per minute of water, which is a 20 to 1 water use ratio by volume. Some operations use less water for the same sluicing rate and this is to their advantage in terms of meeting effluent quality requirements, as will be shown later. Pay gravels mined are taken as being 25% by weight in particles finer than 1 mm, the boundary for 'coarse sand', and 7% by weight in clay sizes. This is an average of size classifications published in the Sigma Report on placer mining (1981). The example calls for using the primary pond for 45 days sluicing production at 7.5 hours per day. After that time the pond has to be cleared out, or a second one must be built.

Primary Pond

In proposing a design for a primary pond, this example chose as a cut-off, a particle size of 46 microns. Although it is quite arbitrary, that size of particle will settle through 1 metre of water at 5° C in a little over 15 minutes, or in an Imhoff cone in 8 minutes. To add a margin of safety, the retention time is taken as 20 minutes. Now 4000 IGPM (18.18 m^3/min) for 20 minutes calls for a minimum volume of 363 m^3 - but this leaves no room for sediment. Sluicing at a rate of

70 yds^3/hr, for 7.5 hours per day, for 45 days, and having to settle 18% (25% sand and smaller, less 7% clay) by weight in the pond means that the pond must be big enough to store the settled fines and still show a minimum retention time of 20 minutes at the end of the 45 day period. Using the factor explained above, the pond must store a sediment volume of 4322 m^3 - a far bigger volume than the water needed to preserve the retention time. The total storage is then 4685 m^3. Enclosing this volume leaves a lot of options - rectangular, square, circular - but given narrow valleys, a design 2 metres deep and with sides in a ratio 4:1, length being four times the width, seems a good compromise. The area needed is 4685 $m^3/2$ m = 2343 m^2 or about half an acre. Solving for the dimensions, $(x)(4x) = 2343\ m^2$, $x = 24.2m$ and the pond perimeter will be $2(24.2m) + 2(4 \times 24.2) = 242$ metres.

Building the pond assumes that the dike is built out of tailings material pushed out of the middle to the sides, and that the dike will have a minimum slope ratio of 3:1 width to height, with half a metre of freeboard for safety and flood prevention. The volume of material needed will be the cross-sectional area of the dike (2 x 1/2 BH, or 2 x 1/2 x 2.5 x 7.5) 18.75 m^2 times the perimeter of 242 m, or 4538 m^3 (5935 cubic yards). For <u>this</u> pond, costs can be estimated using performance estimates and costs for different machines as attached on page 37.

ESTIMATED COST OF A HALF-ACRE PRIMARY POND FOR 70 yd^3/hr

	D7G	D7E	D8L	D8H	D9L	D9D
Yards/hour	272	144	501	286	756	438
Hours	22	41	12	21	8	14
$/hour	131	74	174	89	275	111
$ Cost of pond	$2860	$3050	$2050	$1850	$1780	$1510

These cost estimates will be increased by the cost of the outlet of the pond, which could be a simple ditch or a more elaborate timber dam. A

dam would permit emptying the pond for more frequent cleanout of sediment.

This estimate can be changed to show probable costs for an operation sluicing 120 yds^3/hr with 4000 IGPM. Using calculations like those above, the volume needed for sediment storage and retention time at 45 days will be 7800 m^3, and with a 2 metre depth the area required will be 3900 m^2 or close to one acre. The same 3:1 slope dike and 1/2 m of freeboard will need a material volume of 5854 m^3 or 7656 yds^3. Costs and production rates in the table above allow the following costs to be estimated for 120 yds^3/hr.

	D7G	D7E	D8L	D8H	D9L	D9D
Hours	28	53	15	27	10	17
$ Cost of pond	3670	3922	2610	2400	2750	1890

Secondary Pond

The secondary pond size and cost is much more sensitive to the water volume being treated and to the clay content of the pay gravel. On properties with restricted space the size required and the cost may require the operator to investigate recycling or flocculant use as discussed in other notes. The secondary pond may not need to be completed to its full size before the start of mining as does the primary pond. The reason for this is that the primary pond will have little sediment in it at the outset, and therefore a much longer retention time than 20 minutes. Initially many of the fine silts and clays smaller than 46 microns will settle in the primary pond, and the effluent from this pond will be lower in suspended solids. However, the secondary pond is still needed to settle fine silts and clays after a few weeks of operation. Unlike the primary pond, it should last a full mining season.

A secondary pond with an arbitrarily-chosen retention time of 18 hours should be sufficient to settle fine silts and clays and achieve 1000 mg/l in the effluent. A smaller pond may work for pay gravels low in clays. In the first case, assume an operation with a 4000 IGPM sluicing flowrate. The required volume will be 18.17 m^3/min X 60 min/hr X 18 hr = 19624 m^3; at a depth of 1/2 metre, the required area will be 19624 / 1/2 = 39,250 m^2, or close to 10 acres. In a 70 yd^3/hr operation at 7% clay and fine silt the volume used up by the sediment is much less than that needed for 18 hours water retention time, even in a 90 day season. The perimeter of an enclosing dike, with a 4:1 length to width ratio, will be 990 m. The dike would be 1 metre high to allow 0.3 m freeboard with a 3:1 slope ratio and a cross-sectional area of 3 m^2. The volume of dike material is 990 X 3 = 2970 m^3 or 3884 yds^3. Using cost data and production rates used above;

ESTIMATED COST OF A 10 ACRE SHALLOW POND FOR 4000 IGPM

	D7G	D7E	D8L	D8H	D9L	D9D
Hours	14	27	8	13	5	9
$ cost of pond	1834	2000	1352	1157	1125	1000

The sensitivity of the pond costs to water flows can be seen by calculating the cost of ponds for 2000 IGPM and 500 IGPM flows. For 2000 IGPM the required volume is 9.09 m^3/min for 18 hours or 9820 m^3, which at 1/2 m in depth is an area of 19,640 m^2 or about 5 acres. The perimeter will be 700 metres using a 4:1 length to width ratio, and the volume of fill needed to build it will be 2100 m^3 or 2747 yds^3. Similarly for a 500 IGPM flow with 18 hours retention, the pond area will be 2454 m^3 / 1/2 m = 4910 m^2 or 1.2 acres and the perimeter dike will require 1050 m^3 or 1373 yds^3. Using the machine with the highest dollars per yard cost, the older D7E, shows construction costs for the 2000 IGPM pond to be about $1400, and for the 500 IGPM pond about $700. There seems to be a doubling of cost for every 4-fold increase in flows into an 18-hour retention secondary pond. The operator can over-build this capacity and enhance the retention time without great cost penalties.

Effectiveness of Settling Ponds

The examples given are for a half-acre primary pond two metres deep and a ten-acre secondary pond half a metre deep. Costs of construction on a level, unfrozen gravel surface are estimated at about $2000 each or less, without including costs of ditching between the ponds. For most properties such a system may be effective, provided the operator ensures that the primary pond always has a retention time of 20 minutes or more and the secondary has at least 18 hours and provided that the ponds do not short-circuit and are properly maintained.

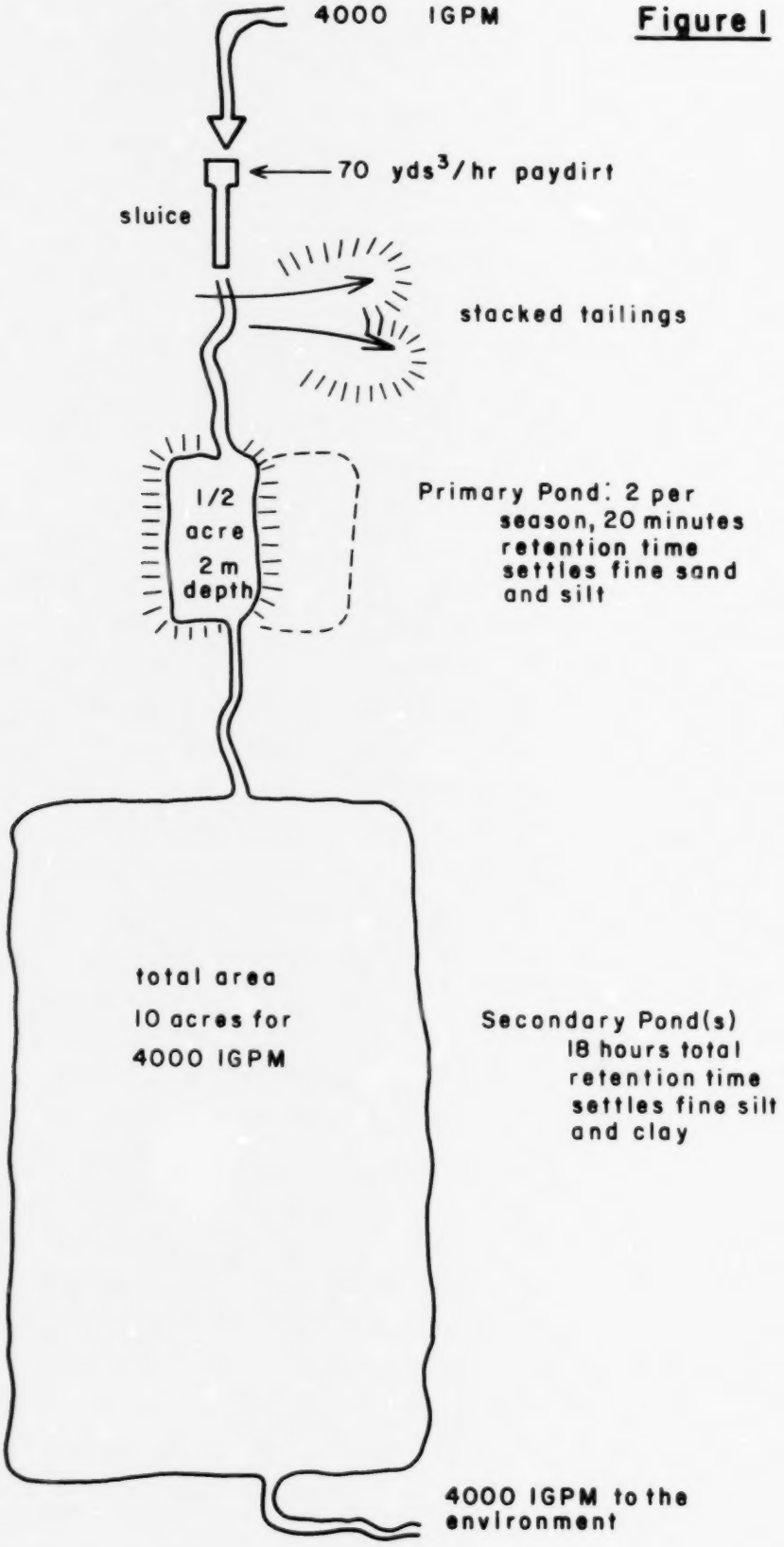
In theory, pay gravels with 7% clay sluiced at 70 yds^3/hr and 4000 IGPM will give an effluent of 2000 mg/l to 4000 mg/l even after 18 hours' retention. However the effectiveness of the pond system will be better than this because some of the clay will settle at every stage in the process. Sedimentation theory describes a second kind of settling known as Type 2, aside from Type 1 or discrete particle settling used here. Type 2 settling or flocculant settling occurs when the individual particles coalesce on their own without adding a chemical agent. The new particles are therefore bigger and settle faster. Type 2 settling can be enhanced by a temperature increase or by natural constituents in the water and other causes. For this reason, the size of the secondary pond is probably conservative, or larger and more costly than will be needed. The individual miner should perform a few carefully-timed experiments with the Imhoff cone and a hydrometer to see if he can comply with the guidelines using a smaller secondary pond.

The worst case for effluent suspended solids control will be on ground in narrow valleys where the miner does not have much room to build ponds, and where his pay gravels contain over 7% of clays. He may be unable to meet a 1000 mg/l guideline without recycling; however such locations may well have a water shortage and the recycling will be needed anyway to meet sluice water requirements. In these cases, the recycle water should be pumped from the outlet of the primary pond.

The secondary pond can then be much smaller, for its size is determined by the flow of make-up water added to the recycle flow. The clay content of the flow passing into the secondary pond will be much higher - but this does not mean that the secondary pond will be ineffective. Some clays have the property of settling faster when they are in a high concentration. This is because the particles are closer together, coagulate naturally, and therefore settle faster. A miner in a high clay, narrow valley situation and using recirculation may find that two small secondary ponds run in tandem may be effective and cheaper.

None of these examples consider the treatment of washings from ground sluicing. Organic muck has a very high fines content. The quantity of fines will very quickly overtax the capacity of the secondary ponds described above and make them useless. Treating the washings from ground sluicing will require a large investment in settling ponds of a size much bigger in area and depth than are described here.

Figure I


4000 IGPM
70 yds³/hr paydirt
sluice
stacked tailings
1/2 acre 2 m depth
Primary Pond: 2 per season, 20 minutes retention time settles fine sand and silt
total area 10 acres for 4000 IGPM
Secondary Pond(s) 18 hours total retention time settles fine silt and clay
4000 IGPM to the environment

SCHEMATIC of SYSTEM for 1000 mg/l

DIAND/EPS
1983/3/4

TAILINGS PONDS AND RECYCLE FOR 100 mg/l

Attaining a suspended solids limit of 100 milligrams per litre depends very strongly on the amount of clay in the pay gravels and the efficiency of water use. If clay content is high, then the operator will have to investigate recirculation of the sluice water, and in some cases it will be necessary to add flocculants to the secondary ponds. One reason in favour of recirculation is that clays settle faster in higher concentrations. A secondary settling pond - relatively large and shallow as compared to the primary pond - will perform better when fed with low, high-concentration flows. Recirculation reduces the volume of water discharged to the environment, but it does add to the costs of mining, both in increased capital costs for the pump and piping and for operating costs of fuel and maintenance.

Recirculation of sluice water poses special problems with wear of the pump parts. The suspended material, even though it is more clay than silica, causes wear of the pump impeller and more importantly of the pump journals and glands. Modern pumps operate at high speeds compared to older, heavier pumps, and when they are directly coupled to small diesels turning at 2000 RPM or more, they need careful operation and maintenance. Another problem of pump use is the suction location. Centrifugal pumps need to be primed, or placed so that their suction is level with the pump inlet because there is a severe loss in efficiency for a suction lift to the impeller pump.

A second problem with recirculation is that the returned water carries a heavy charge of suspended material back to the sluice box. According to some dredge operators, if the suspended solids content exceeds a specific gravity of 1.100 (or approximately 60,000 mg/l suspended solids) then there is a risk of losing some fine gold from the sluice. None of the recycle schemes proposed here will exceed this value, but its importance is questionable anyway. Mineral process engineers at the University of British Columbia report that a typical placer sluice operation recovers only 50% of gold particles smaller than 'fine sand',

minus 100 mesh or 150 microns. Since the change in specific gravity from 1.000 to 1.100 is small with respect to that of gold (15-19.3), suspended solids content of recirculated water is not an important factor at these concentrations. The shape of the gold particles, their surface roughness or the presence of inclusions are far more important factors in gravity recovery, and it is well known how these will vary from creek to creek in a district.

The system proposed for attainment of 100 mg/l is similar to that for 1000 mg/l, with the addition of recirculation. The miner will need two settling ponds, a primary and a secondary at the outset. As the primary pond fills in with sand and coarse silt, its retention time is being reduced so that the suspended solids content of the effluent from it will rise continuously. Eventually even after further settling in the secondary pond, the final or secondary effluent will exceed 100 mg/l without further treatment. Here the miner has the option of building a third pond, large and shallow like the second; but if he has a room problem, he will have to install a recycle system. If the miner knows he has a high clay content in his pay gravels he should investigate recycle at the outset because even a string of settling ponds may be insufficient to meet the lower limit.

Recirculation calls for pumping waters flowing from the first or primary pond back to the dump box of the sluice. Any degree of recirculation is possible depending on pump size, but some fresh water is needed to make up for water bound up in wet tailings awaiting stacking or lost in seepage. The costs of recirculation will be the capital costs of the pump, the prime mover, necessary piping to the sluice, and the works necessary to install the pump and suction at the pond outlet. The operating costs would be for amortization of the machinery, maintenance of the pump - especially the glands and journals - and fuel for the pump motor. Pump size and the amount of recirculation depends at least in part on the water supply available to the miner. Total recirculation or zero effluent is discussed in separate notes. Where water supply is not a problem, then the miner's choice of recycle rates for

sluicing high-clay pay gravels may depend on his need for flocculants, since it is much cheaper to treat a small, concentrated flow than a large, dilute flow.

It is worth emphasizing here that there are many unknowns about Yukon placer mining. They are the quantities and kinds of clay found in placer gravels, size distributions of gold particles, the range of grades of pay gravels and the recoveries or efficiencies of typical operations. Some creeks have clays which may never settle without flocculants. Others may settle when in high concentrations, but not at levels 1000-2000 mg/l. The Sigma Report (1981) mentions one creek where the water had properties which promoted natural flocculation. Because of these unknowns, a miner on a 100 mg/l guideline creek will have to do some experimenting to find the treatment system that is best for his ground, both in terms of grade and clay content, especially before he begins making an investment in pumps, piping and large quantities of flocculants. He will have to construct a primary pond at the outset, and prepare at least a small secondary pond, but he may defer ordering some materials until he can predict the settling behavior of the clays.

Costs of Recirculation without Flocculants

The same assumptions will be used in these examples as for the 1000 mg/l system. A primary settling pond is constructed with its size proportional to the pay loading rate; 70 yds^3/hr for 45 days at 7.5 hours per day requires a pond of about half an acre in area, while 120 yds^3/hr for the same period needs a pond an acre in area, and both rates will use 4000 IGPM. Costs for these ponds have been estimated. Recycle costs will be shown for two cases, 50% recycle or 2000 IGPM and 87% recycle or 500 IGPM.

The secondary settling pond is proposed to meet 18 hour retention time for each effluent, 2000 IGPM for 50% recycle and 500 IGPM for 87% recycle. Costs to be estimated are for the primary pond, recycle pump,

engine, installation, piping and secondary ponds. Pump operation costs will be shown as cents per yard sluiced.

Assumptions for cost estimation of pumping are as follows; the suction of the pump is below the water level, giving better mechanical efficiency. The pump discharges through 300 m or 1000 ft of 12 inch diameter welded steel pipe through a discharge head of 8 m (25'). The maximum concentration of the suspended solids gives a specific gravity of 1.100. The pump operates for 7.5 hours per day for a 90 day mining season.

For 50% Recycle, Pumping 2000 IGPM:

Pump engine 42 HP continuous, diesel*	$5000.	
Pump, Ni-Hard or rubber-lined	3000.	
Piping at $7 per foot	7000.	
Installation costs, tank etc.	2000.	$17000.

* Perkins 4154

Operating Costs: 0.40 lbs/BHP-Hr fuel consumption for a naturally-aspirated diesel, 70 l/day at $.506/l, maintenance at $1/hr or $8/day, $42 for a 7.5 hour day.

Financing Costs: assume 15% financing, tax credits and tax on sale of unit and pipe at end of 3 years and recovery of 35% of purchase price. Net present value of $17,000 is $7004, over 90 days' operation at 7.5 hrs/day is $10.37/hr. Thus total pumping costs for operation and financing are $120/day.

Cost per yard for pumping for 70 yds^3/hr = $.22/yd
for 120 yds^3/hr = $.13/yd

Note that there is a clear cost incentive to economize on water use when in a recycle situation.

Secondary Pond Costs: The required volume will include room to settle 90 days' clay production at 70 yds^3/hr and 18 hours' retention time. A 2000 IGPM discharge for 18 hours needs 9819 m^3. Seven percent clay in 70 yds^3/hr will settle at a density of 416 kg/m^3 and needs 12,168 m^3. Allow .5 m water depth in the pond when full with clay. This yields a pond size of 4.8 acres, in a 4:1 length to width ratio. Total depth will be 1.7 metres, allowing for .7 m for clay storage, .5 m for water and .5 m freeboard. Volume of the perimeter dike will then be 7928 yds^3 and bulldozer costs can be estimated as for the 1000 mg/l ponds: 55 hours for a D7E = $4074 and 18 hours for a D9L = $2009.

For 87% Recycle, Pumping 3500 IGPM:

Pump engine 72 HP continuous, diesel*	$7500.	
Pump	4000.	
Piping	7000.	
Installation Costs	2000.	$20,500.

* Perkins 4236

Operating Costs: 115 l/day = $58, maintenance = $9/day.
Financing Costs: Net present value $9276/90 days = $103/day.

Total daily operating cost of $170/day can be expressed as cost per yard, for 70 yds^3/day = $.33
for 120 yds^3/day = $.19

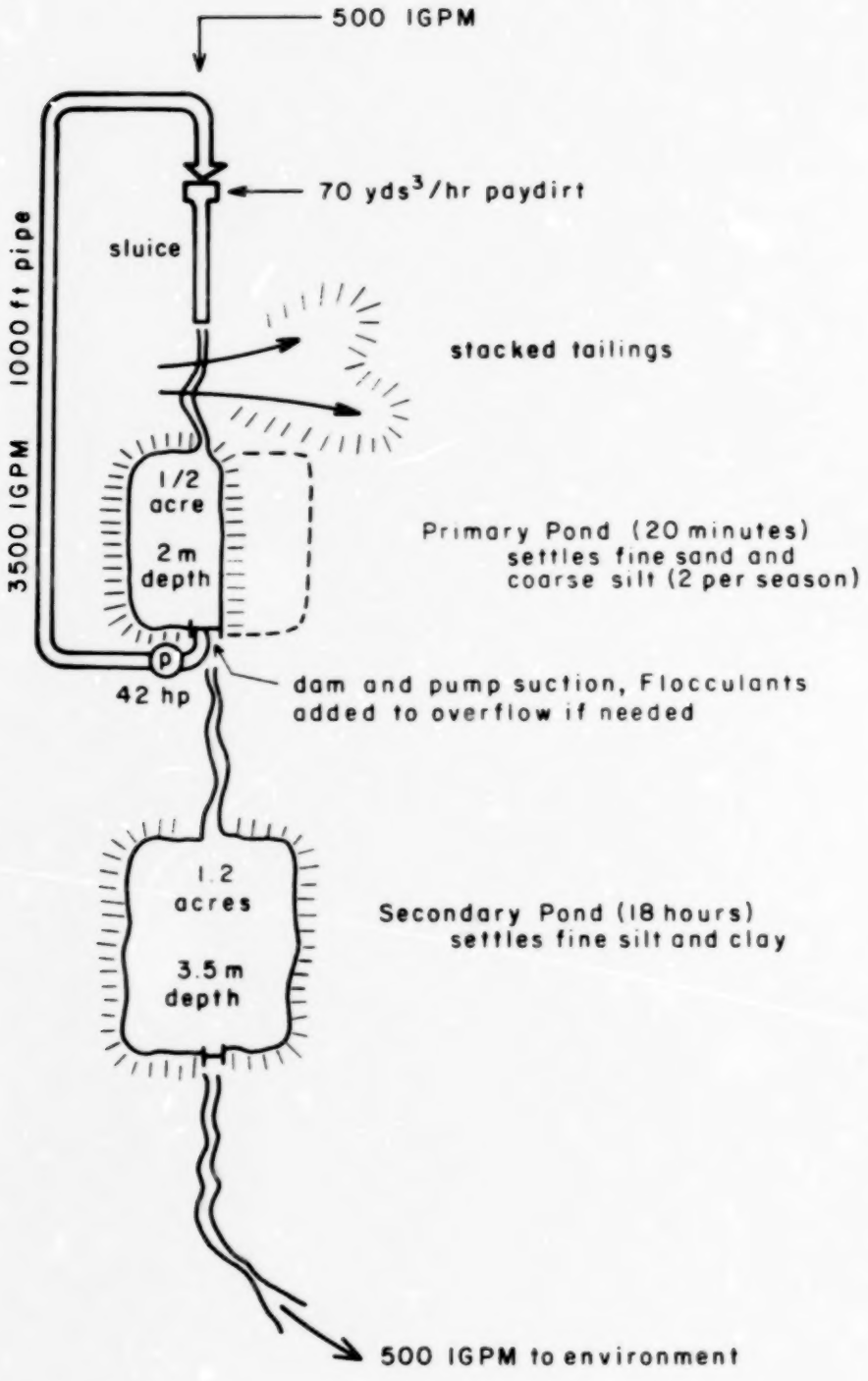
Secondary Pond Cost: The volume for 18 hours' retention is 1/4 that for 2000 IGPM, but the clay volume is the same. A minimum water depth of .5 m must be maintained to prevent wind/wave resuspension of the clays and fine silts. This causes the pond to be deeper than for the 2000 IGPM effluent. An area of 1.2 acres for a total volume of 14,619 m^3 requires a depth of 2.48 m for clay and silt storage, plus 1 m for water and freeboard. That 3.5 m depth and the same 4:1 length to width ratio requires a dike of volume much larger and more costly than for

the 2000 IGPM secondary pond, 20,187 yds^3 instead of 7928. Bulldozer costs are therefore estimated, 140 hours for a D7E = $10,373 and 46 hours for the D9D = $5115.

These costs for a small deep pond suggest that it may be more economical to build two 500 IGPM secondary ponds during the course of a season where space permits, as is suggested for the primary pond. Note that these pond sizes are sensitive to the gravel sluicing rate. Ponds designed to handle quantities of fine sand, silt and clay at 70 yds^3/hr will soon be swamped by sediment at 120 yds^3/hr.

The essential features of these notes for a 100 mg/l system should be summarized. The reason for recycle is to concentrate the level of suspended solids in the effluent. This is because fine silts and clays tend to settle faster when they are in a relatively high concentration. Without recycle, the miner would have to construct a series of large ponds to settle the clays and meet a 100 mg/l objective. He may not have the room for this, and the cost of additional ponds has to be considered. Recycling 2000 IGPM seems to be cheaper than recycling 3500 IGPM in a 4000 IGPM water duty to the sluice, both from the point of pump operating cost and secondary ponds. It is not possible to estimate an optimum rate of recycle without knowing the approximate percentage of fine silts and clays, or the cost of make-up water delivered to the sluice, or any of a dozen different factors peculiar to each claim.

Figure 2



SCHEMATIC of SYSTEM for 100 mg/l EFFLUENT

DIAND/EPS

1983/3/4

TAILINGS PONDS AND RECYCLE FOR ZERO EFFLUENT

A few placer mining streams in the Yukon may have the requirement that waters discharged after sluicing may not show an increase in suspended solids above background concentrations. In these situations the miner is forced into a total recycle situation, drawing only small quantities of makeup water to replace that lost through seepage from his operation. The system to be used is only slightly different and more costly than for a 100 mg/l system, because an additional pumping stage may be needed.

The miner will need a primary settling pond the same as that described for the 1000 mg/l requirement, one capable of storing fine sands and coarse silts for 45 days' production. The effluent from this pond can be recirculated in a way as described for 100 mg/l, that is by returning some part of the total 4000 IGPM sluicewater flow back to the dump box. It is not possible to return the whole flow, because the suspended solids - depending on the clay content of the pay gravel - will concentrate rapidly. A discharge from the primary pond and a secondary settling stage will be needed. The difference between the 100 mg/l and the zero system is that the effluent from the secondary pond has to be pumped back to the dump box as well. However this secondary pump does not need to be in operation throughout the 90 day season.

Initially the primary pond will have very little sediment in it, and the total flow from this pond can be recycled. Since the operation will not be operating 24 hours per day, the build-up of fines will be reduced by overnight settling. Eventually the reduced retention time of the primary pond and the concentration of clays will require a reduction in the recycle flow from this pond so that some of the suspended matter can escape to the secondary pond. This secondary effluent after 18 hours' or more settling can be returned to the dump box with an additional pump system. The cost of the additional pump system is the principal difference betwen the 100 mg/l and the zero systems.

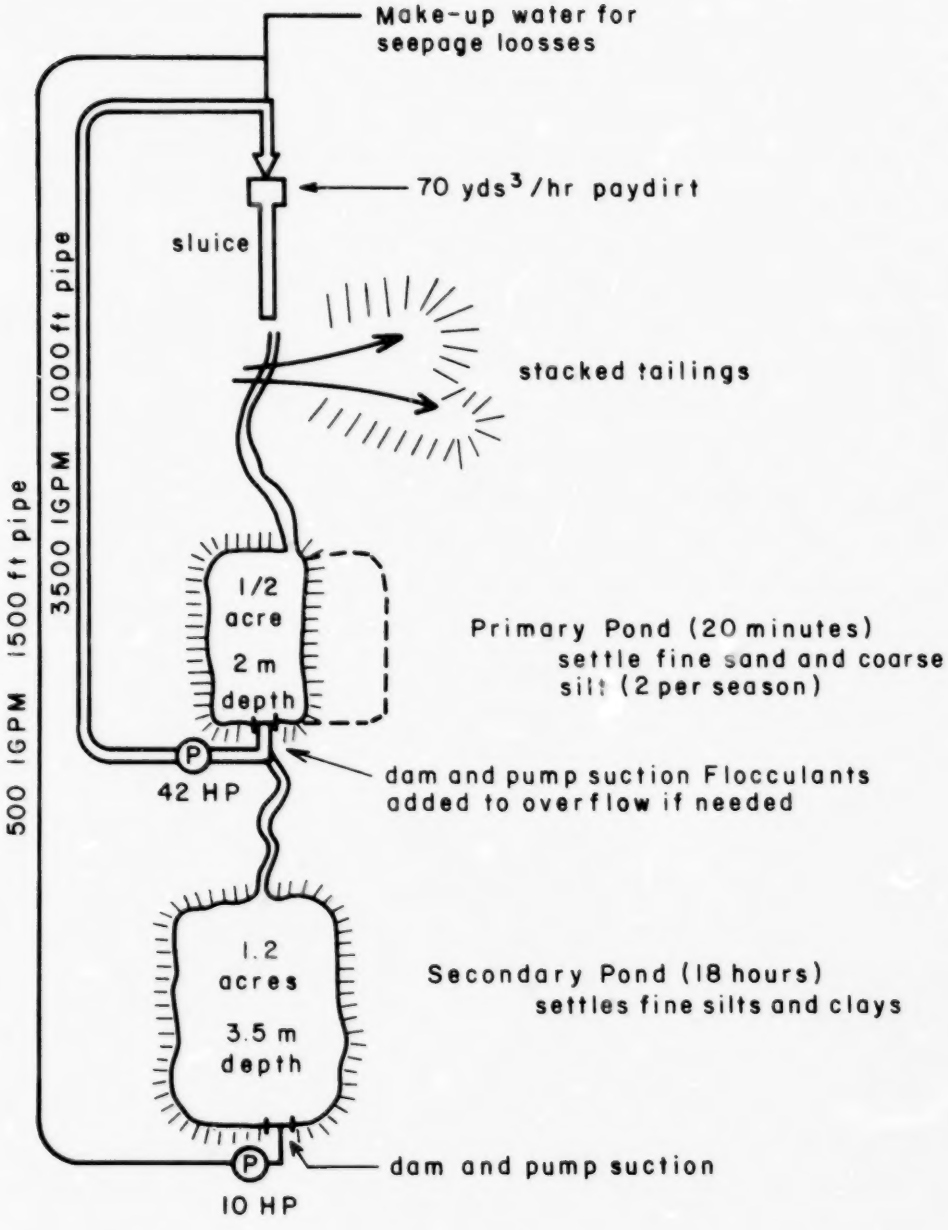
Pumping costs for 2000 and 3500 IGPM have been esitmated; the additional costs for a zero effluent system would be for a smaller pump system, and 500 IGPM will be used.

Pump engine 10 HP continuous, diesel	$3500	
Pump, centrifugal	1500	
Piping, $4 per foot, 1500 ft.	6000	
Installation costs, tank etc.	1000	$12,000

Operating Costs: fuel consumption
16 l/hr at $.506/l = $8/hr., maintenance = $.50/hr, $64/day
Financing costs: net present value $5428/90 days = $60/day
Total daily operating cost of $124/day can be expressed as cost per yard, for 70 yds^3/hr = $.24
for 120 yds^3/hr = $.14

This example has used 2 pumps, one at 3500 IGPM and the secondary pump at 500 IGPM. Depending on the miner's water duty to the sluice and the percentage of clays, some other balance of pumps would be more cost effective. Note that the output of the small secondary pump could be connected to the 12" line from the primary recycle pump to save on pipe costs.

Figure 3



SCHEMATIC of SYSTEM for ZERO mg/l EFFLUENT

(TOTAL RECYCLE)

DIAND/EPS
1983/3/4

COST ESTIMATES OF CLOSED CIRCUIT WATER SYSTEMS FOR PLACER GOLD MINES

A limited survey of placer gold miners currently operating in British Columbia was conducted to determine some actual costs of closed circuit water systems. From the responses a profile of an operating placer gold mine was compiled and provides some representative costs.

B.C. classifies all provincial rivers and streams as red, yellow, or green for the purpose of regulating placer mining. In red coded watercourses the restrictions on water contamination are the most strict. The key requirement is that "All wash water shall be recirculated in a closed system so that there will be no discharge of sediment-contaminated water into any watercourse. Settling ponds shall be located above the normal high-water level of any watercourse." The requirements for yellow coded streams are somewhat less stringent requiring that sediment-contaminated water "shall be contained and/or treated prior to discharging any watercourse." Green coded streams have less rigid regulations but contaminated water must also be contained or treated.

Seven placer gold mine operators were interviewed. They provide a reasonable cross section of the industry in the length of time in business, size of operation, level of expenditures. As a general disclaimer however it must be pointed out that this information is verbal and anecdotal in nature and is neither a random nor statistically valid sample.

Before presenting the data gained from this survey a brief overview of some of the opinions of these miners will give some background to the industry in B.C. First, none of them was able to make a comparison between open and closed sytems since all of them had worked on only one type. Since only one with an open system was interviewed any comparisons are weak. However that open system required three ponds to meet effluent standards whereas closed systems had more than one pond out of choice. Unfortunately that distinction between open and closed systems

gets a little cloudy in the presence of significant amounts of groundwater. In several of the systems described there was drainage out of the pond through the gravels and makeup water came from seepage. Several of them seem to view the surrounding substrate as a huge filtering system. Strictly speaking the washwater was not fully recycled. Therefore the costs presented here may understate the costs of a truly closed system, i.e. one with plastic lined ponds etc.

Secondly, although it is well appreciated it must be stated that the costs of placer gold mining are very site specific depending on the contours of the land, the nature of the gravels. Equally important, though not so often expressed, is that the costs of placer mining are a function of the individual miner. There is no single widely accepted technology and most of the miners have no special training in placer mining techniques. A great deal therefore depends on the inventiveness, judgement, and level of practical skills that each miner has. Finally, all the miners felt that the recycled water might reduce the capture of very fine (or flour) gold, although two were confident that they caught everything that could be captured with sluice technology.

Type of System:

Of the seven miners interviewed six had closed systems and one had an open system. Among the sluices there was one shaker sluice, three static sluices, and three Turner boxes. The Turner box is peculiar in being about 40 feet wide and 2 feet long. It operates on screened paydirt and low water volumes. It is highly regarded for having a high capture rate.

The volume of pay gravels varied between 50 and 600 cubic yards per day with a volume of 400 yards being most common. In all seven operations the gravels were screened down to 1 1/4 inch or smaller. The combination of screening and the use of the Turner box substantially reduces the water demand and therefore the size of settling ponds.

Ponds:

In most cases ponds were used but two miners used only one pond and one miner sometimes used four ponds. The ponds varied from a combined size of one tenth of an acre to one acre. Although size was not exactly related to either pump size (ie. water volume) or paydirt volume it does appear that usually the larger the pump the larger to total pond area. The ponds varied from six feet to fifteen feet deep. The bottoms were often of clay so that plastic coating was not used. However, seepage seemed to be a desired feature for two reasons: one, to provide clear makeup water; and two, to allow the surrounding substrate to act like a giant filter.

The dikes were usually only half the depth of the pond as the ponds were dug down into the ground and the material pushed up to form dikes. They varied from 10 feet to 60 feet across the top. There were no problems with the dikes in any of these operations although there were some seepage and leakage problems. In these cases the ponds were drained and leakage through large loosely-packed gravel was plugged with layers of silt and clays.

Cleaning of the ponds varied from once a week to never. Once a year seemed most usual. The ponds would tend to drain through seepage over the winter and dry out. Before operations commence in the following spring the sediments would be plowed out and saved for covering in rehabilitation. It reportedly takes about half to a full day to clean the ponds. In all cases the ponds are used or can be used for more than one mining season and sometimes for as long as four seasons.

Cost of Ponds:

The time necessary to build the ponds varied from seven hours to eighty hours. The length of time required to build ponds appears to be inversely related to the length of time the operator has been a placer gold miner. Fifteen to twenty hours seems to be the most likely time required. One miner interviewed said his time was virtually nil

because the gravels that he moved for the pond were the first that he processed and then used the resulting hole as a settling pond. He didn't want to attribute costs to pond building.

The values quoted for equipment and operator time ranged from $50 to $100 per hour. These were usually the rates that the B.C. Forest Service or the B.C. Ministry of Highways paid for equipment of this type. The rates are dependent on the size, age, and special features of the particular piece of equipment. If $75 per hour is taken as an indicative hourly cost for the machine and operator and if under average conditions somehow defined a settling pond takes 20 hours to build, then such a pond would cost $1,500 (the extremes would be $350 and $8,000). When asked what proportion of annual costs were attributable to settling ponds two said it was virtually nothing, two said less than 5%, one said 10% and two said 15% to 20%. Once again there was an inverse relationship between the cost proportions and length of time the miner had been in operation.

Pumps:

Most of these miners operated with only one pump - make-up water often came from ground water seepage. The pumps varied in size from 3" to 8" outlet with 6" pumps being the most common. The few secondary pumps that were used or kept as standby were from 2" to 4". The pumps varied from $5,000 to $20,000 with $15,000 being the most likely price. The miners expected the pumps to last from 3 to 10 years with major repairs about every two years. Ten years was the most commonly given life expectancy particularly for the more expensive pumps.

Earth Moving Equipment:

Earth moving equipment was of two types in general - a bulldozer and a loader. Caterpillar was the most common type and D6, D7 and D8 were the sizes used. Loaders varied more in style than bulldozers and had buckets varying in capacity from 1 1/4 to 4 1/2 cubic yards. The equipment was all purchased as used with few exceptions and ranged in

price from $30,000 to $155,000. The $50,000 to $70,000 range was the most common. A probable value for earth moving equipment per miner would be $100,000 to $120,000 including both bulldozer and loader.

Operating Season:

The operating season for B.C. placer gold mines is according to this group, from 150 to 260 days although 150 to 180 seems the most probable. About 65% of that time would actually be spent mining while the remainder would be spent repairing equipment, moving operations, cleaning up mined areas and other maintenance chores.

Cost of Ponds in Dollars Per Yard:

Taking the percentage of operating season and the length of season gives the number of operating days. From this the seasonal volume throughput is calculated and then multiplied by two, since all settling ponds were used for at least two years. The total two year volume was divided into pond building costs to yield a cost of paydirt throughput in dollars per cubic yard for the ponds. This value ranged from $0.01 to $0.12. This amount should be adjusted up slightly for pond cleaning, maintenance and additional pump wear. The adjustment would however be very small.

Conclusions:

1. The initial cost of digging one settling pond is approximately $1,500 to $3,000. A second pond is preferred but will usually be dug in the excavation of pay gravels.
2. Some pond cleaning and maintenance will be required but depending on the site should not exceed 5 to 6 days per season.
3. There will be some additional wear and tear on pumps but this is seen as negligible. Pipe costs may or may not be an additional cost as settling ponds may a closer water supply than natural watercourses.
4. Some fine gold may be lost because of the increased specific gravity of wash waters that are being circulated but with a careful operation this should be a small amount.

5. The cost of pond construction in terms of dollars per yard of paydirt over the lifetime of the pond is approximately $0.04 on average.
6. While costs of all things vary considerably depending on the site the choice of sluice, technology and the screening of pay gravels prior to sluicing can substantially reduce water demand and therefore the size of the settling ponds. In addition the individual miner's skill and ingenuity are a major factor in reducing costs.

USE OF FLOCCULANTS IN PLACER MINING

A flocculant is a chemical compound which causes clay particles in water to stick together, and makes them settle faster. On those creeks where a placer miner has a high clay content in his paydirt and a space limitation which prevents him from building large secondary ponds, he should consider using flocculants to lower suspended solids in water leaving the settling ponds.

The action of a flocculant can be seen and understood by means of a simple experiment, by adding lemon juice drop by drop to a cup of coffee with milk. The acid in the lemon juice causes the fat particles in the milk to curdle or lump together and then sink to the bottom of the cup. A flocculant removes clay from water in much the same way, and the effective doses of flocculants can be very small - less than one part per million may be quite effective in most cases. In the low concentrations proposed here, they are not toxic to fish in the receiving water. They are not a health hazard if handled carefully.

The biggest problem is that there is no proven compound and dosage which will work better than others. The clay content of paydirt in one creek will be different from another both in quantity and in type, and the chemistry of the creek waters will be different as well. If a miner finds that he cannot meet one of the recommended standards for suspended solids, he could try adding a small quantity of one or more of the flocculants discussed below to settling pond water to see if they give an improvement. The flocculants have to be experimented with to find the best type and the best dose for the money. These experiments do not need to be difficult or expensive, and some flocculant manufacturers will assist in this testing.

In order to understand what a flocculant does to clay particles it will be helpful to consider the kinds of clays a miner could find, and to describe the kinds of flocculants available. A common type of clay in

Klondike streams would be those formed from mica-like minerals - sericite, muscovite and chlorite. These minerals can be abundant in shales, schist or gneiss bedrock. Clay particles formed by those minerals settle very slowly because they carry a slight electrical (ionic) charge. This may cause the particles to repel each other so that they cannot stick together to form larger particles or flocs.

A flocculant changes the electrical characteristics of the water holding the clay particles. If the particles have a high ionic charge, the flocculant will need to have an opposite ionic charge. For many Yukon placer streams, one type which seems to be promising is a synthetic, organic compound called polyacrylamide. This compound may be neutral in charge, or charged positively (cationic) or negatively (anionic) depending on the type. Dissolved in water, the compound forms long, spaghetti-like molecular chains. If it is a charged type, each long molecule attaches to it all the nearby clay particles having an opposite charge. The molecules form flocs in this way, and because the new particles are much larger and neutralized in their charge, they sink more rapidly than smaller, isolated clay molecules.

Using a flocculant will add costs to mining, but these costs can be kept low if the miner reduces the quantity of water to be treated, and adds the agent to water that has undergone some minimum settling time of at least 15 to 20 minutes. Efficient use requires at least some recycling of water so that flocculant is added only to those flows draining from the first or recycle pond to the final pond. It is much less expensive to treat 500 or 1000 gallons per minute than 4000. Secondly, recycling of sluice water will concentrate the amount of clay in the effluent, which assists the efficiency of the flocculant dosages and makes this treatment more cost-effective.

The suggested use of flocculants can be described in an example. A typical small placer operation might sluice 70 cubic yards per hour of paydirt with 4000 gallons per minute, with a conventional 3 by 40 foot sluicebox. Flows from the 20 minute recycle pond might be 4000 gallons

per minute or less depending on the percentage of recycle that is possible. This example is of a 20 to 1 water to paydirt ratio by volume, so if some pre-classifying is used and the water use ratio is less than 20 to 1, then the cost estimates for water treatment are valid for operations processing more than 70 yards per hour.

Costs are shown in the table below for Separans® MG200 manufactured by Dow Chemicals and supplied in Vancouver at $8.21 per kilogram. This is a powdered anionic polyacrylamide which was tested and found effective by Sigma Resources Consultants Ltd. in their 1981 report on placer mining. Other equivalent compounds would be Percols® 90 L, 110 L and 120 L made by Allied Colloids (Canada) Inc., Clarifloc® made by Allied Chemical, and SuperFloc® 1292 made by Cyanamid. This brief cannot endorse any one compound over others.

CALCULATED AVERAGE COST (FOB VANCOUVER) OF POWDERED FLOCCULANT FOR VARIOUS FLOW RATES AND DOSAGES, PER 7.5 HOUR SLUICING DAY.

Treated Water Discharge rates	Dosage in Parts per Million			
	0.5	1	2	4
500 I.G.P.M.	$ 4.70	$ 9.30	$ 18.60	$ 37.20
1000	9.30	18.60	37.20	74.40
2000	18.60	37.20	74.40	186.00
5000	46.60	93.20	186.00	372.00

The preparation and addition of flocculant is not difficult. A one percent solution of the compound is prepared by taking 2 kilograms or 4.5 lbs of the powder and mixing it into 45 gallons of clean, preferably warm water. Thorough and careful mixing is extremely important. It can be done with a variable speed 3/8 electric drill, or a small 12 v

electric outboard motor turning at a low speed. After one hour of intermittent mixing, the solution can be added to the effluent or discharge flow as a slow stream through plastic tubing with a metering valve. A flow of 31 litres per hour of a 1% mix is sufficient to put 1/2 part per million dose into a flow of 500 gallons per minute. Larger flows and higher doses will need correspondingly larger holding tanks and flow rates for the compound.

Using a flocculant has one other complication. They are expensive enough reagents to cause the miner to be careful about the quantities he adds to achieve a desired amount of settling, but calculating the amount used requires him to know quite accurately the amount of water or the flow rate he is treating. This can be done by building a simple measuring device at the outlet of the recycle or primary settling pond.

As an example, at the outlet of the pond a stoplog dam can be built and provided the top of the dam is dead level, measuring the depth of water flowing over it will give a good estimate of the water flow. Also, the turbulence below the dam would be an excellent place to add the flocculant. A dam eight feet or 2.5 metres long, level and with a sharp edge, will have 5.6 cm depth of water passing over it at 1000 I.G.P.M., or 3.6 cm at 500 I.G.P.M. If the dam was four feet long or 1.25 metres, these depths would be doubled. Measurement has to be slightly upstream or away from the falling curve of water, and it is taken from a zero point which is dead level with the top of the dam. Depending on the material being mined, a trash rack or screen may be needed to keep floating debris from lodging against the dam.

This foregoing section has been an attempt to describe what a flocculant is, and to suggest costs for treating different flow rates. The costs and the suggested methods should be seen as a starting point for the miner's own research into treatment methods and costs tailored to his own claim.

USE OF THE SOILS TESTING HYDROMETER IN PLACER MINING EFFLUENT CONTROL

The soils testing hydrometer (ASTM 151H) is a rapid, inexpensive and fairly accurate means of testing for suspended silts and clays in placer mining. Placer miners could benefit from using it in two ways, by monitoring the silt content of water during recycling, and by ensuring compliance with a 1000 mg/l effluent standard.

The principle behind a hydrometer is the same as that used in measuring antifreeze concentrations, or in testing the charge in a battery. A fully-charged automotive battery will show a hydrometer reading of 1.250 to 1.3000 (in the green scale), meaning that a litre of that acid will weigh 1.250 to 1.300 kilograms. A hydrometer float will register 1.000 in pure water at 20°C. If we add say 10 grams of silt and clay to a litre of that water and mix it well, the hydrometer will then read approximately 1.006.

The divisions on a soils tesing hydrometer run from 1.040 down to 1.000 and below, in divisions of .001. The amount of silt and clay suspended in water can be estimated by moving the decimal point three places to the right and multiplying by 60%: 1.030 gives 30 x .60 = 18 grams per litre or 18,000 milligrams per litre (mg/l).

In practice the use of the hydrometer is a little more complicated. Its readings are very sensitive to temperature. If we read 1.040 in cold water at 5°C, its readings at 20°C would be 1.038; so the true solids contents would be a little lower: 38 X .6 = 22,800 mg/l instead of 24,000. The hydrometer should be used with a good quality mercury thermometer accurate ± 1°C, and a conversion chart to go from SG readings to mg/l, with temperature corrections. This will make sure that if the test water and the effluent or recycle water are not at the same temperature, the difference can be allowed for.

The ordinary soils hydrometer is not accurate enough to distinguish between 100 mg/l and 200 mg/l suspended solids. With some care one can estimate the difference between 1000 mg/l and 500, or between 500 and 100 or less. More accurate hydrometers are available, but their use will require more careful attention to solution temperatures and the time taken to make a reading.

The miner should appreciate what it is he is trying to measure. The particles in a test solution are already settling even while the hydrometer measurement is being taken. If he is using a 40 cm deep Imhoff Cone to measure solids in the tailing water, the cone should be undisturbed and no readings should be taken on the hydrometer for eight minutes. This is equivalent to particles of the same standard size settling through one metre of water in a pond with a retention time of 20 minutes, which is time enough to settle coarse silt, or particles larger than 46 microns.

Miners know that the water used for sluicing does not need to be clear, and that it is possible to recycle water. There are practical limits to recycling in that if the sluicing water gets too loaded with sediment, some gold will be lost. The hydrometer can warn the miner when it is time to add cleaner water to the sluice, or stop the recycling and let the water settle for a while. Dredge operators have said that if the water attains a specific gravity of 1.100 -- or 60,000 mg/l suspended and settleable solids -- then there is risk of gold loss. The soils hydrometer has a maximum of 1.040 or 24,000 mg/l so it cannot be used to measure higher concentrations. The miner could regulate his recycle water to 24,000 maximum through appropriate retention and settling, or use an ordinary battery hydrometer for measurement, since most models will show a 1.100 reading at the top or red end of the float.

Finally, miners may find an hydrometer useful to test the solids content of water at the bottom of the sluice. Through experimentation he may find that very high loads of fine solids there lead to gold

losses. The hydrometer may be of help to balance his water and paydirt loadings to the sluice. Making placer mine water use as efficient as possible will help both gold recovery and sediment control in the tailings.

OPERATING COSTS FOR NEW BULLDOZERS

Calculated from 1982 Caterpillar Performance Handbook using "average" to "severe" factors for terrain and use; $.80 U.S. per $1.00 Canadian; 1.20 for isolation, freight; $0.506/litre for diesel fuel delivered in quantity at Dawson. Each machine fitted with ripper and universal blade.

Owner's Cost in Dollars Per Hour, Excluding Operator and Financing.

	Fuel	Grease, Filters	Under-Carriage	Other repairs	Hourly Cost, $
D 7	19.10	1.08	18.00	8.75	47.00
D 8	23.00	1.83	22.80	12.50	60.00
D 9	30.60	2.23	30.00	16.90	80.00

Capital Costs and Depreciation

	1983 Cost $ FOB Whitehorse	Resale† Value $	Financing; 3year* write off, $/hour
D 7	230,000	34,500	63.60
D 8	310,000	46,500	93.50
D 9	415,000	62,500	125.00

† Service life 7,500 hrs at 1500 hrs/year for 5 years.
* Using 15% financing, includes tax credits and tax on sale at end of 3 years recovering 35% of purchase price.

Hourly Cost Comparison, Owned vs Rental Units

	Financ-ing	Labour	Fuel	Supplies	Rental*	Total Rental	Total Owned
D 7	63.60	20.	19.10	1.08	70	110	131.
D 8	93.50	20.	23.00	1.83	100	145.	174.
D 9	125.00	20.	30.60	2.23	150	203.	225.

* Verbal quote from local supplier, includes undercarriage and repair costs.

Used machines unencumbered by debt are estimated to have hourly operating costs 55% less than those of new machines shown above through savings in financing costs, having identical fuel and labour requirements but showing a 20% increase in undercarriage and repair costs.

CALCULATION OF BULLDOZER PRODUCTION (p.37)

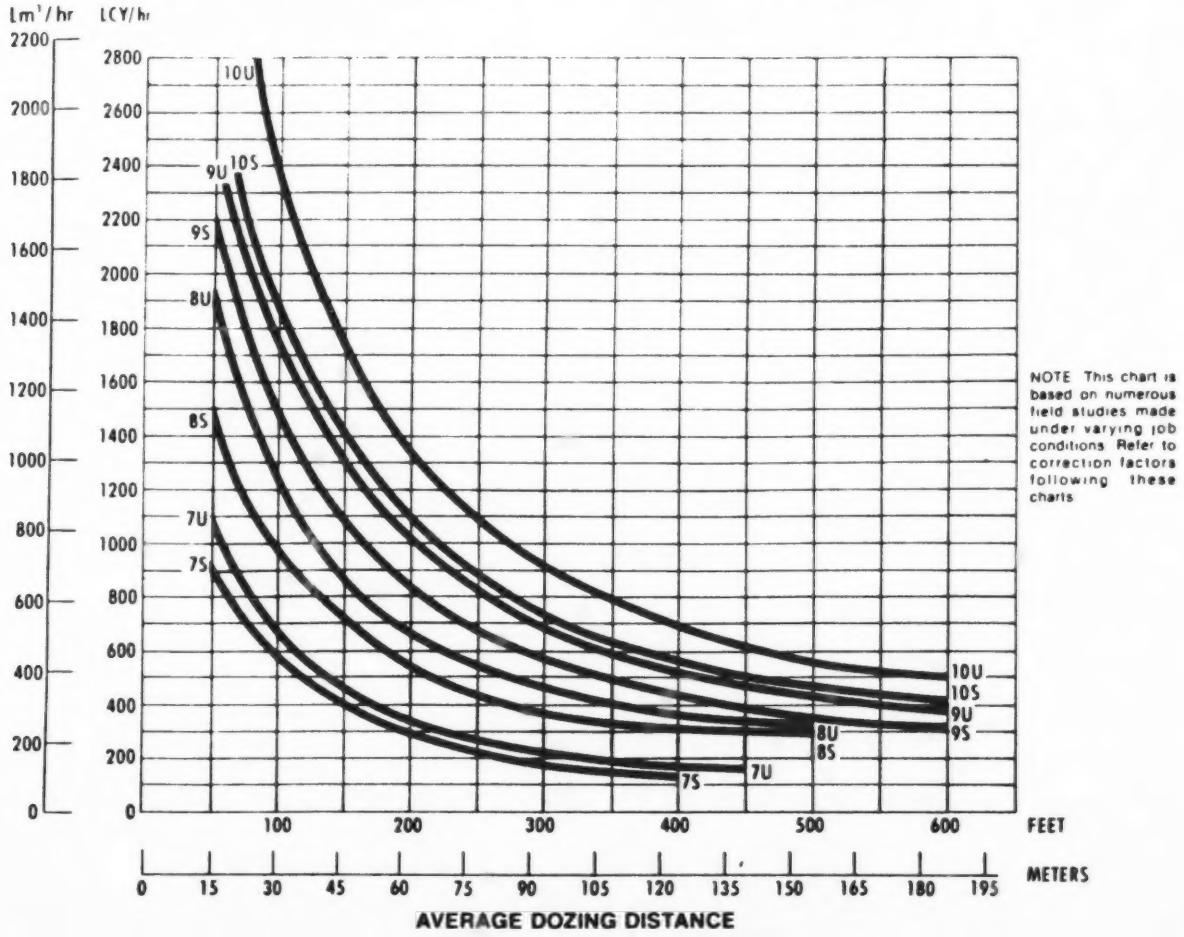
From: Caterpillar Performance Handbook, Caterpillar Tractor Co., Peoria, Ill., October 1982.

Notes: Operator efficiency=0.75; 50 min/hr. = 0.84
Material Correction: loose material 1.20 and rock 0.80 combined yields .96 for tailings; allow 0.80 for frozen material.
Travel distance of 50 m or 164' taken as typical.

	D7G	D7F*	D8L	D8H*	D9L	D9G*
Horsepower	200	180	335	270	460	385
Loose cubic yards/hour (derived from curves below)	450	248	830	473	1250	725
Corrected for average op	338	186	622	354	938	543
Corrected for tailings	324	172	597	340	900	521
For frozen ground	270	149	498	283	750	434
50 min/hr for tailings	272	144	501	286	756	438
frozen ground	227	121	421	240	635	368

*Production figures for these 1970 models are derived by downrating 1982 curves by 55%, on the basis of rated drawbar pulls as published. Actual production will lie between these values and those calculated from horsepower factors.

ESTIMATED DOZING PRODUCTION • Universal and Straight Blades • D7 through D10



FINES CONTENT OF PAY GRAVELS
IN SOME ALASKAN AND YUKON STREAMS*

Location and Creek		Weight Percentage Finer Than 0.046 mm	0.02 mm
Alaska:	Miller Creek	36.	14.8
	Gilmore Creek	30.	14.0
	Fish Creek	15	12.2
	Gilmore Creek	18	7.7
	Mastodon Creek	25	5.9
	Eagle Creek	16	5.7
	Deadwood Creek	15	5.5
	Independence Creek	12	3.8
	Faith Creek	11	3.5
	Crookes Creek	5	2.9
	Eagle Creek	4	2.6
	Chena River	8	2.6
	Fairbanks Creek	6	1.3
	Independence Creek	4	1.2
Yukon:	Henderson Creek	8	3
	Duncan Creek	6	4
	Little Gold Creek	6	6
	Clear Creek	7	5
	Matson Creek	6	5

Notes:

1. Particles larger than .046 mm or 46 microns will settle through one metre of still water at 5°C in 20 minutes.

2. Particles larger than 0.02 mm or 20 microns will settle in an Imhoff Cone in one hour at 5°C, and would be 'settleable solids'.

3. Particles finer than 0.02 mm will not settle in an Imhoff Cone, and would therefore be 'suspended solids'.

*Sources:

"Placer Mining Wastewater Settling Pond Demonstration Project Report" by R & M Consultants Inc., Alaska, 1982.

"Water Use Technology for Placer Mining Effluent Control" by Sigma Resources Consultants Inc, 1981.

Documentation supplied to the Yukon Water Board for public review on licence applications, 1982.

GRAIN SIZE SCALES FOR SEDIMENTS

U.S. Standard Sieve Mesh #		Millimeters	Microns	Wentworth Size Class
5		4		
6		3.36		
7		2.83		Granule
8		2.38		
10		2.00		
12		1.68		
14		1.41		Very Coarse Sand
16		1.19		
18		1.00		
20		0.84		
25		0.71		Coarse Sand
30		0.59		
35	1/2	0.50	500	
40		0.42	420	
45		0.35	350	Medium Sand
50		0.30	300	
60	1/4	0.25	250	
70		0.210	210	
80		0.177	177	Fine Sand
100		0.149	149	
120	1/8	0.125	125	
140		0.105	105	
170		0.088	88	Very Fine Sand
200		0.074	74	
230	1/16	0.0625	62.5	
270		0.053	53	
325		0.044	44	Coarse Silt
Analyzed		0.037	37	
	1/32	0.031	31	
by	1/64	0.0156	15.6	Medium Silt
	1/128	0.0078	7.8	Fine Silt
Pipette	1/256	0.0039	3.9	Very Fine Silt
or		0.0020	2.0	
		0.00098	0.98	Clay
Hydrometer		0.00049	0.49	
		0.00024	0.24	
		0.00012	0.12	
		0.00006	0.06	

PRICES FOR PLACER MINING WASTEWATER TESTING DEVICES

As shown in the 1982 Catalogue of Fisher Scientific Ltd.:

Vancouver Office
196 West 3rd Avenue
Vancouver, B.C. V5Y 1E9
(604) 872-7641

Edmonton Office
10720 - 178th Street
Edmonton, Alberta T5S 1J3
(403) 483-2123

Item	Catalogue Number	Description	Price
Imhoff Cone	15-438-2	Standard	$13.81
Thermometer	15-021B	Pocket Model with case, 1°C	$ 9.82
Hydrometer	11-583C	Precision model for 0 - 10,000 mg/l suspended solids	$ 9.87
Soil Hydrometer	14-331-5B	for 0 - 40,000 mg/l suspended solids (ASTM # 151H)	$22.37
Hydrometer	11-520A	For recycle water for 0 - 200,000 mg/l solids	$ 9.40
Graduated Cylinder	08-570-21G	Plastic, 1 Litre	$13.44
Graduated Cylinder	08-532D	Glass, 1 Litre	$15.96

TABLE OF EQUIVALENTS AND FORMULAE

Imperial gallon	= 1.20 US gallon	= 0.161 cubic foot
Imperial gallon/min	= 1.20 US gallon/min	= 2.67×10^{-3} cubic ft/sec
Imperial gallon	= 4.55×10^{-3} metres^3	= 4.55 litres
Imperial gallon/min	= 7.57×10^{-5} metres^3/sec	= 7.57×10^{-2} l/sec
Imperial gallon of water	= 10.02 pounds	= 4.55 kilograms
Cubic foot of water	= 62.4 pounds	= 28.3 kilograms
Cubic metre of water	= 2204 pounds	= 1000 kilograms
Acre	= 43,560 square feet	= 4047 square metres
Cubic yard	= 27 cubic feet	= 0.765 cubic metres
Cubic metre	= 1.308 cubic yards	= 35.3 cubic feet
Cubic metre bank gravel	= 2 tonnes (metric)	= 2.21 tons
Cubic yard bank gravel	= 1.53 tonnes (metric)	= 3370 pounds

STOKES LAW (WADELL'S FORMULA)

Describes the settling velocity for small discrete particles:

$$V = \frac{1}{7} \frac{(d_1 - d_2)gr^2}{n}$$

V = settling rate cm/sec
d_1 = particle density (specific gravity)
d_2 = fluid density
g = gravity constant, 981 cm/sec^2
r = particle radius in centimetres
n = kinematic fluid viscosity-for 5°C = .01519 cm^2/sec, 10° = .01307, 20° = .01002

RECIRCULATION FORMULA

Obtained from 'Water Use Technology for Placer Mining Effluent Control, Sigma Resource Consultants (DIAND, 1981).

$$T = \frac{-V}{Qm} \ln \left[\frac{S - (QmC_1 \times 3 \times 10^{-7})}{S - (QmC_0 \times 3 \times 10^{-7})} \right]$$

T = time in minutes to a desired concentration (C_1)
V = volume of pond in imperial gallons
Qm = Flow of make-up (fresh) water, imperial gallons/minute
ln = exponential notation (if ln A=x, then A=e^x)
S = tons per hour of suspended solids (material that will not settle out in the pond)
C_0 = background concentration of suspended solids, mg/l
C_1 = maximum concentration of suspended solids, mg/l

POOR

QUALITY

ORIGINAL